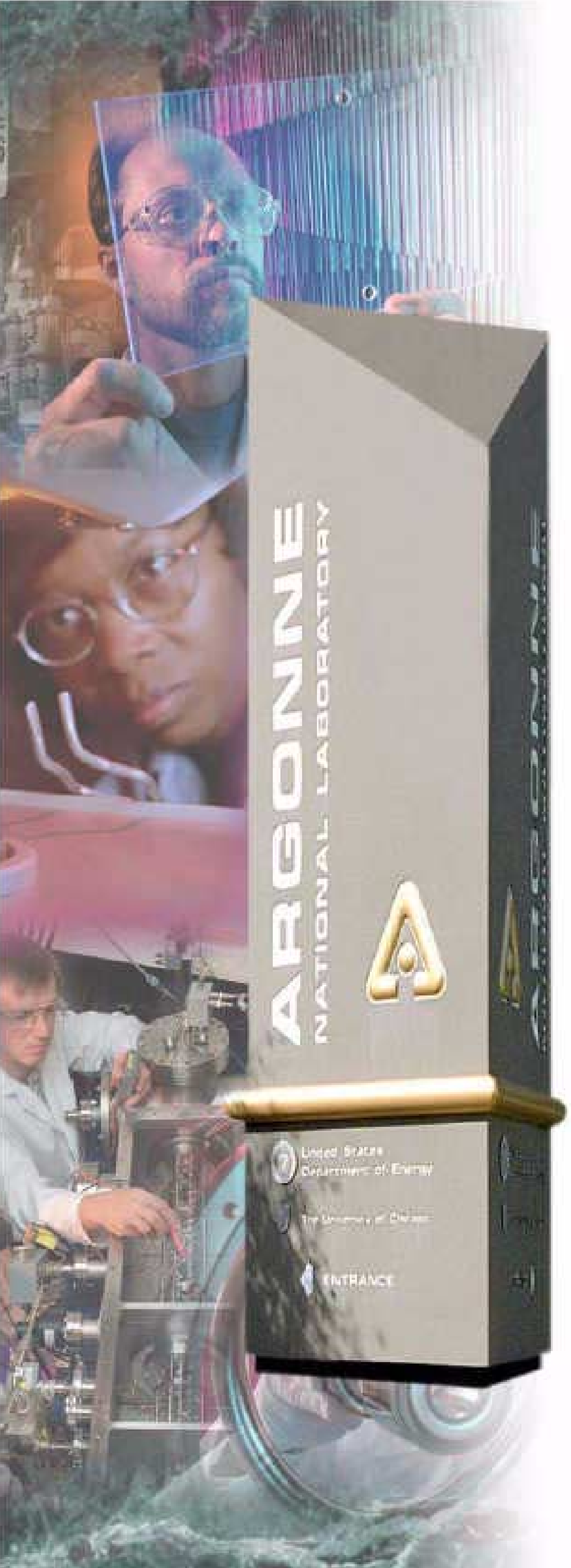


ADVANCED PHOTON SOURCE
APS OPERATIONS DIVISION

Hard X-ray Beam Position Monitor Design Review

Glenn Decker

February 3, 2004

- Charge to the committee
- Some history
- Development of an ultimate beam stability specification
- Present storage ring performance and limitations
- Strategy for achieving 200 nrad / week pointing stability

Charge to the Committee

Comment on proposed beam stability specification

Will the proposal provide the capability to meet the specification.

A simple, widely distributed survey asked 5 questions:

- Are you satisfied with the stability of the x-ray beam arriving at your sample?

ID: *Yes= 2, No = 16, Undecided=1* BM: *Yes=3, No = 1*

- Do you use any feedback to stabilize your beam?

ID: *Yes = 10, No = 9* BM: *Yes=2, No = 2*

- Have you determined at your beamline the relative contributions to the beam instability from the source and from the beamline optics?

ID: *Yes = 8, No = 11* BM: *Yes = 3, No = 1*

- Is there a class of experiments that is made difficult by the present level of stability on your beamline?

ID: *Yes = 15, No=2, Undecided = 2* BM: *Yes=2, No=2*

- If APS will help with diagnostic of beam stability, will you use such service?

ID: *Yes=16, No = 0, Undecided = 3* BM: *Yes=4, No=0*

APS Beam Stability Requirement

Original Stability Specification
Equivalent to 5% of Particle Beam Dimensions*:

Vertical: 4.4 microns / 0.45 microradians rms
Horizontal:16 microns / 1.2 microradians rms

Translating this 5% requirement to the present low-emittance / low coupling lattice results in**:

Vertical: 0.42 microns / **0.14** microradians rms <----
Horizontal:13.5 microns / 0.53 microradians rms

* Y.C. Chae, G. Decker, “APS Insertion Device Field Quality and Multipole Error Specification, PAC ‘95§

** http://www.aps.anl.gov/asd/oag/SRSourceParameters/sourcePointResults/

Insertion Device Pointing Stability Specification

$$\sigma_{y'_{xray}} = \frac{\sqrt{(1+K^2)/(2nN_u)}}{\gamma}$$ = X-ray vertical opening angle

$$\gamma = E/(mc^2) = 13700$$ @ 7 GeV

N_u = Number of undulator periods
= 72 for APS und. A

n = undulator harmonic number

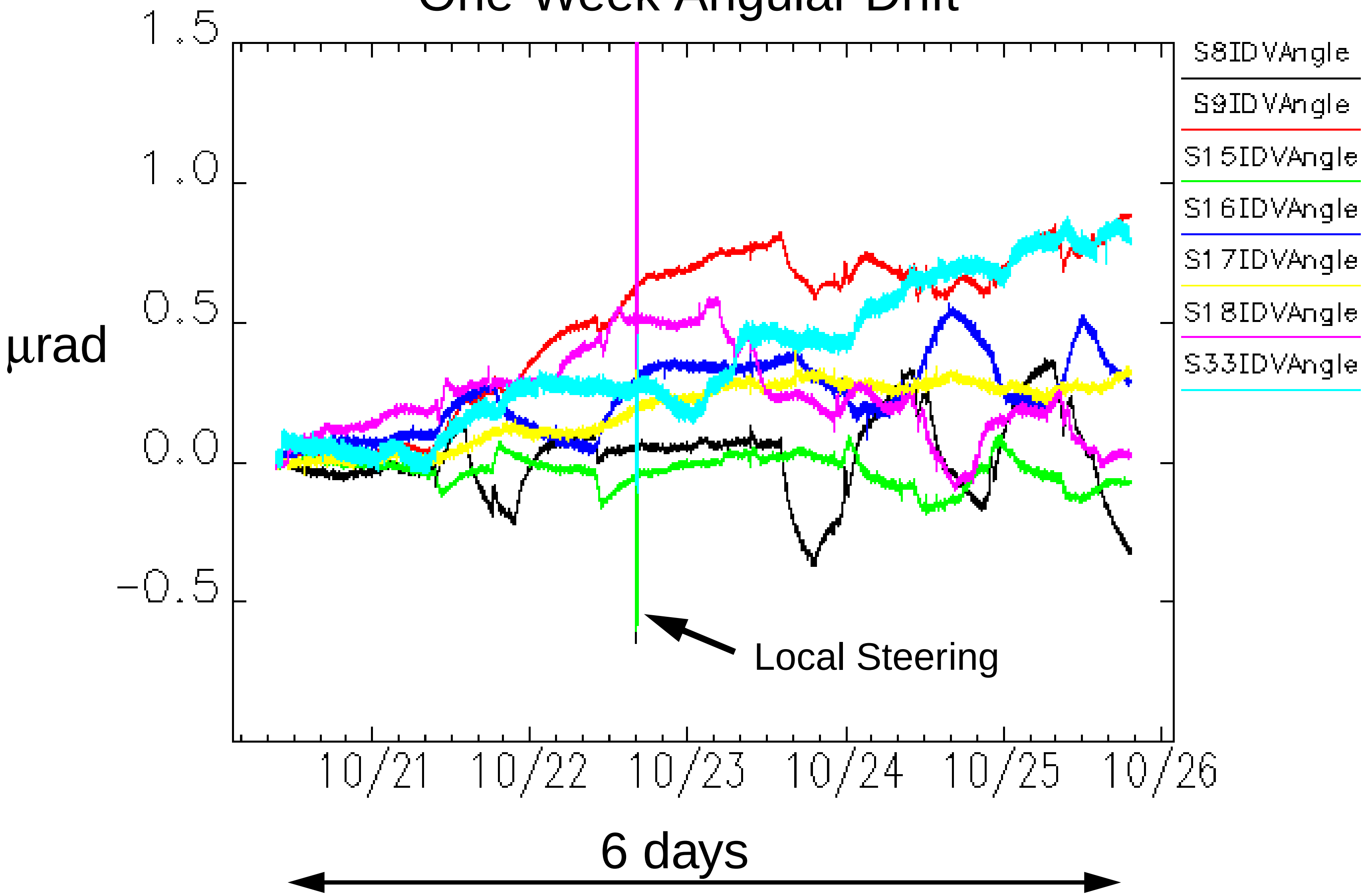
$\therefore\ \sigma_{y'_{xray}}$ = 3.3 μrad rms (n=7, K=1)

This adds in quadrature with the electron beam divergence $\sigma_{y'_{e^-}}$ = 2.9 μrad

$\sigma_{y'_{total}}$ = 4.4 μrad

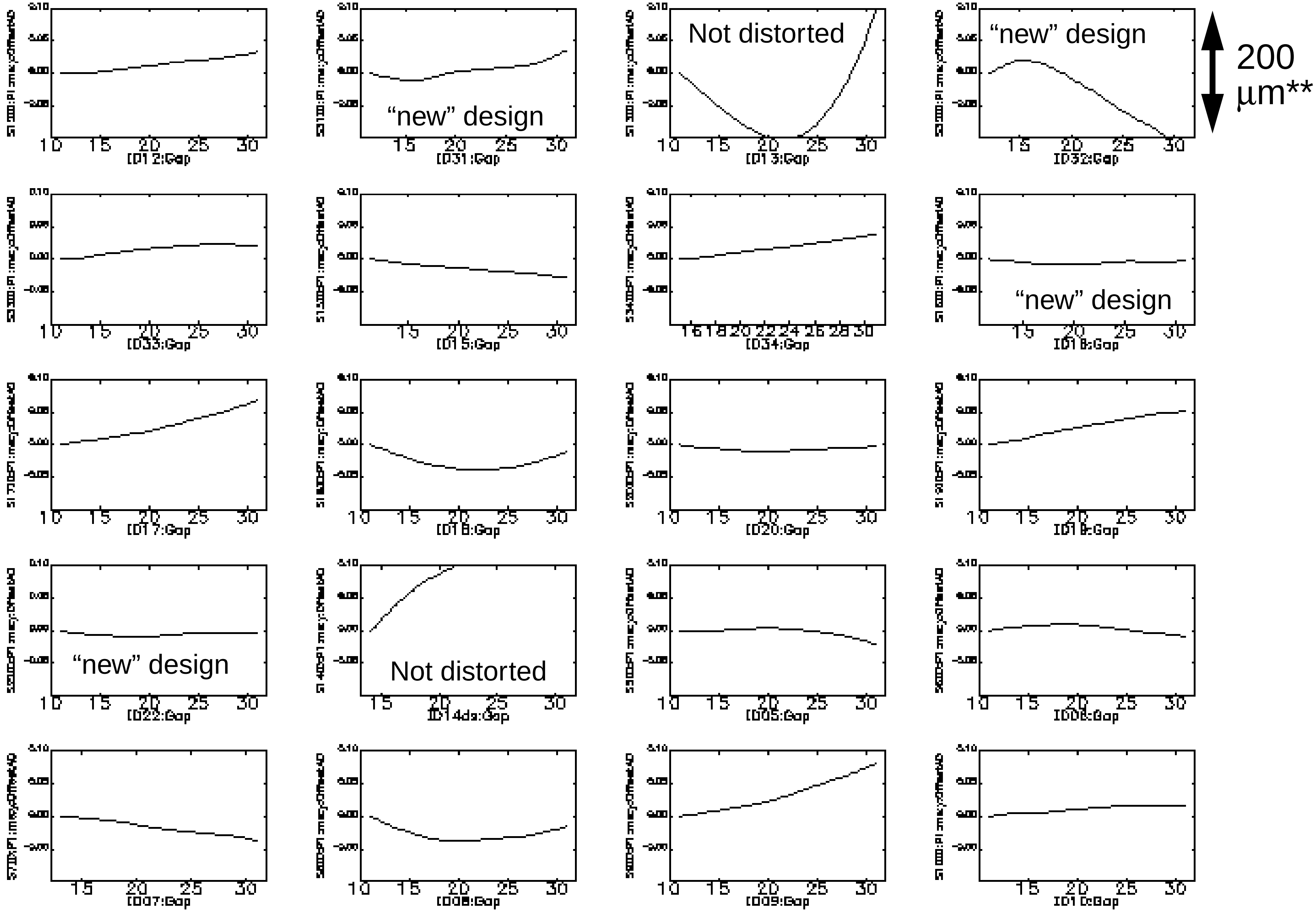
$\boxed{\text{Pointing stability} = 0.05 \star \sigma_{y'} = 220 \text{ nanoradians rms}}$

One-Week Angular Drift*



*Slope of best fit straight line using both rf bpm's and P1 ID photon bpm (*fixed gap*)

ID Photon BPM Offset vs. Gap Lookup Tables (P1 Vertical*)

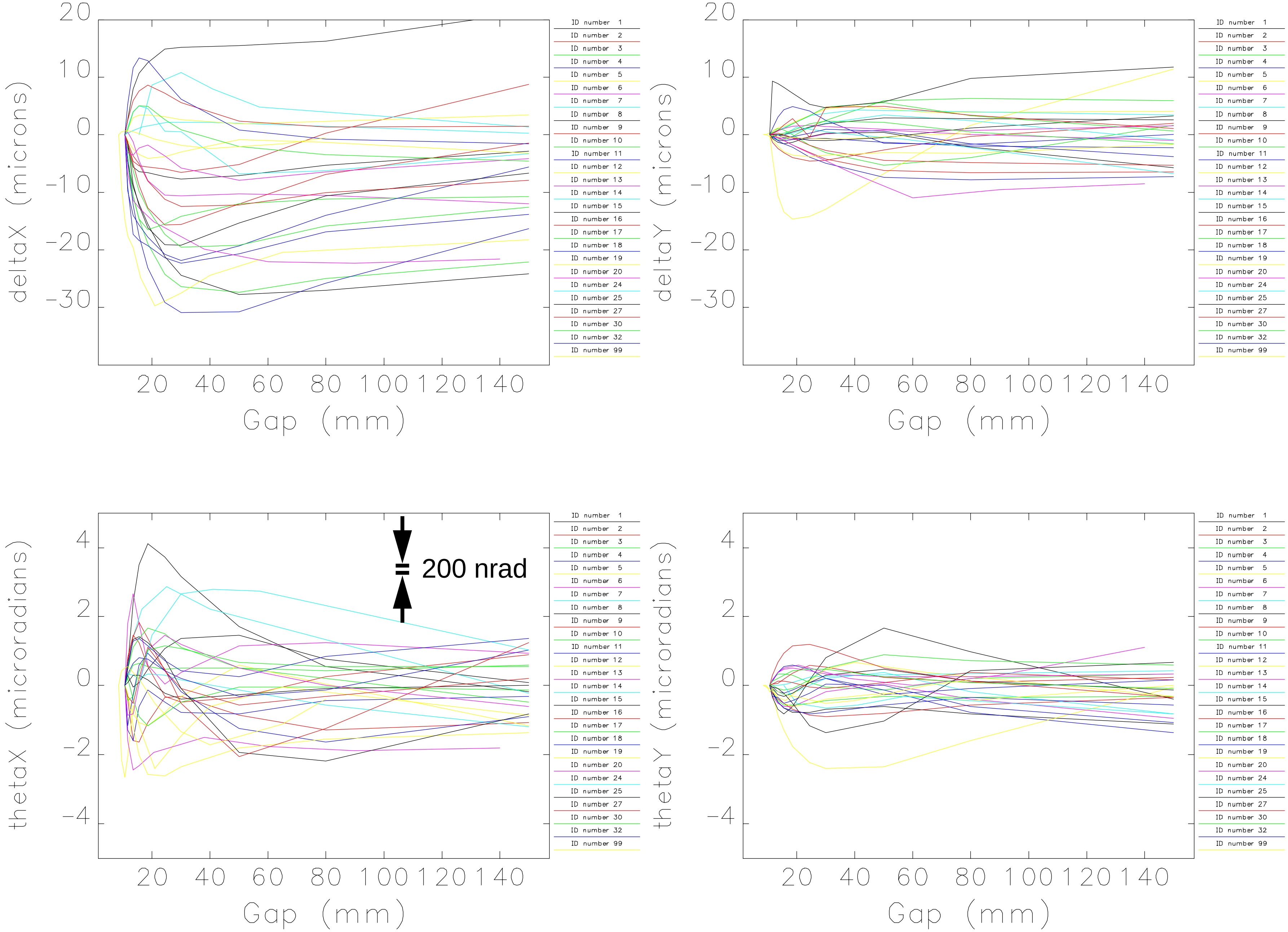


* Our most reliable units

**Equivalent to approx 12 µrad

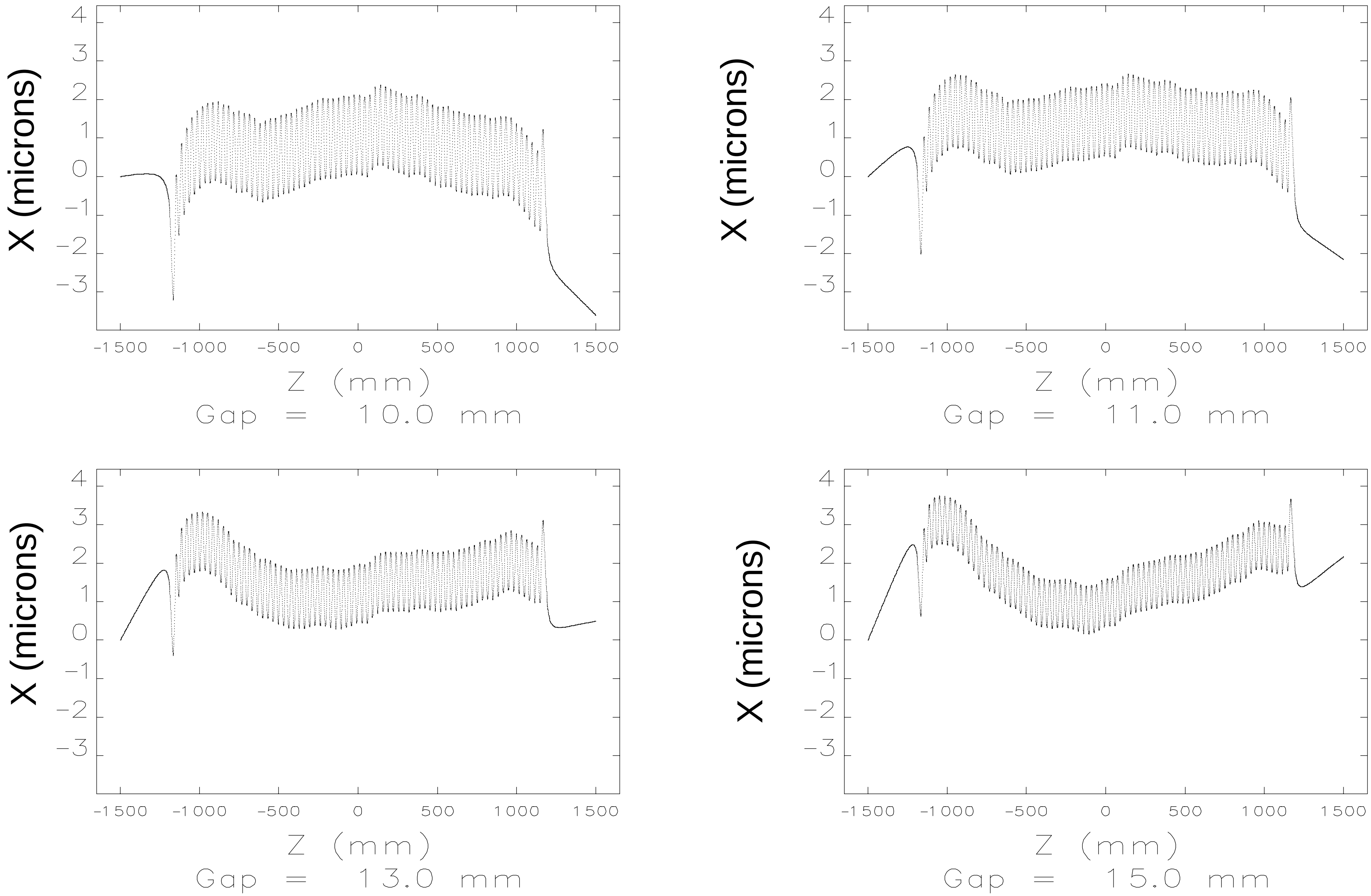
Insertion Device Field Integrals vs. Gap

(Rotating Coil Data)

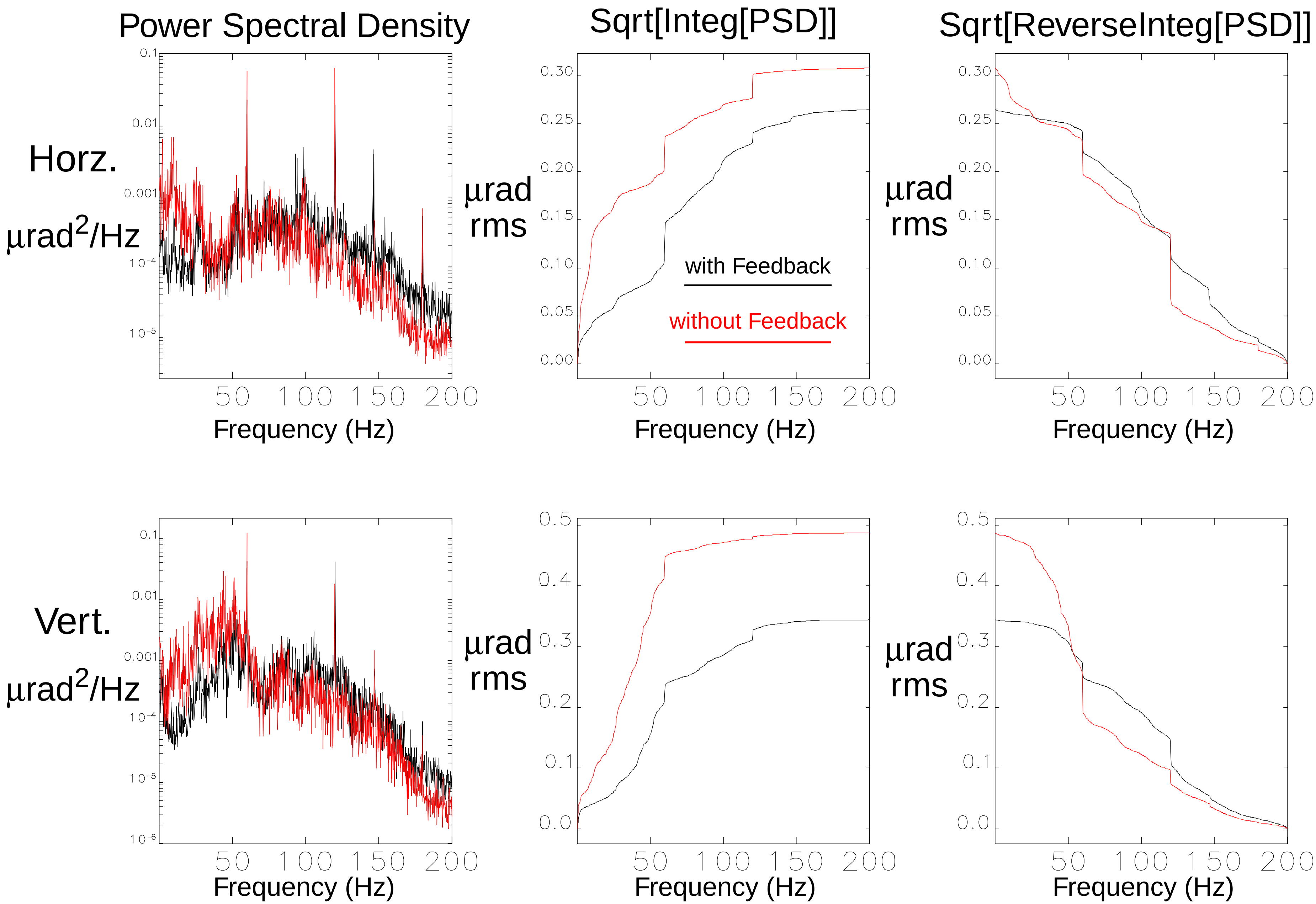


Variation of Particle Trajectory Through Insertion Device vs Gap

(Derived from Second Field Integral of Magnetic Measurement Data)



AC Pointing Stability



Summary of Factors Limiting Long-term Pointing Stability

- Tunnel temperature +/- 0.1 degrees C is mandatory.

- ID photon bpm residual gap-dependent systematic errors

  - Internal trajectory errors cause particle / x-ray beam non-colinearity

  - RF bpm's (measuring particle beam trajectory) are used to generate lookup tables for ID photon bpm offset vs. gap

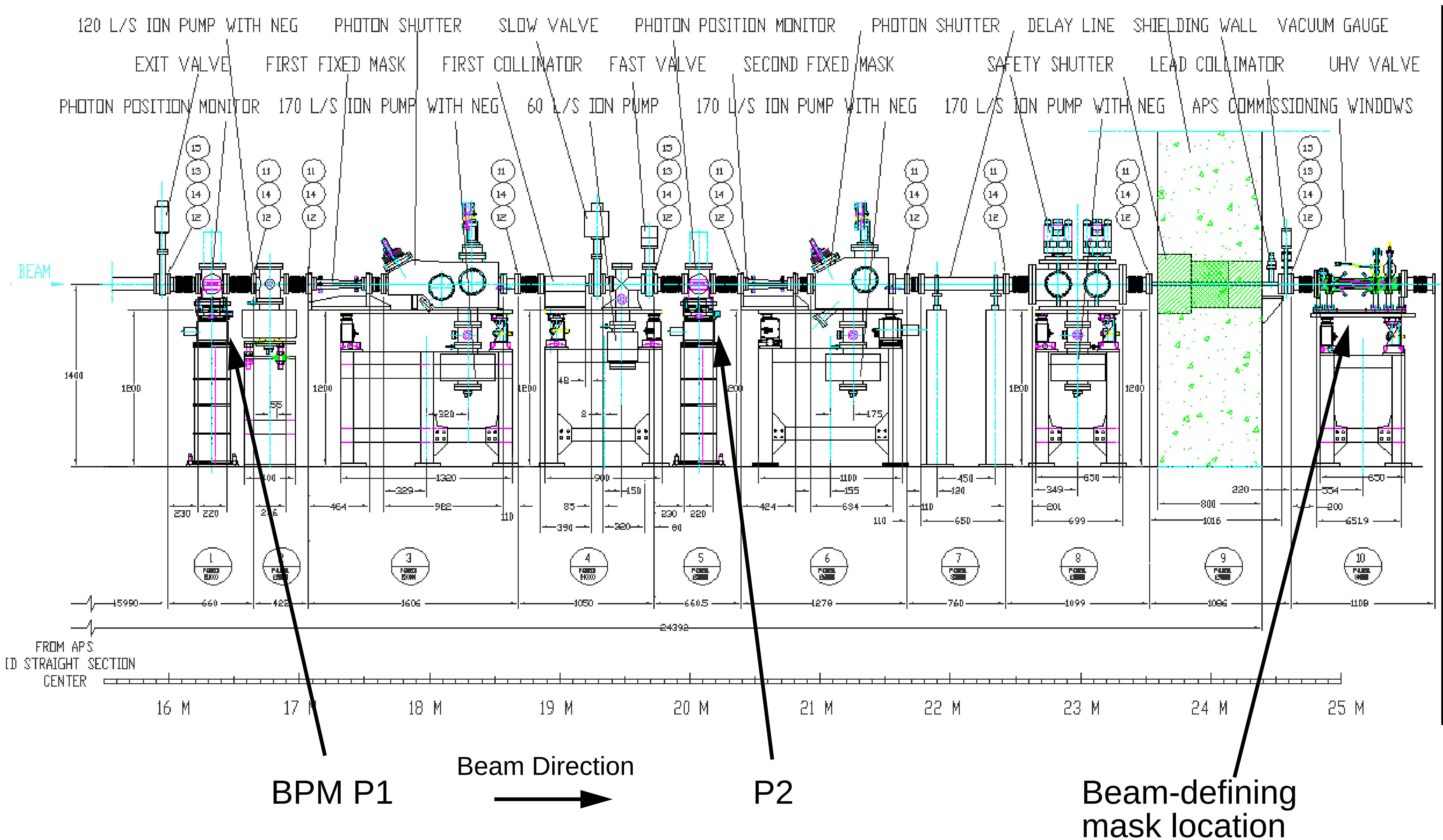
  - Photon bpm's are sensitive to bending magnet radiation, causing significant background signal, important at large ID gap.

  - Sensitivity to ultraviolet radiation halo causes other problems, e.g. electron cloud effects.

- The direction of the x-ray beam centroid relative to the particle beam is indeterminate at the few-μrad level using present technology.

  - A diagnostic sensitive only to hard x-rays is necessary to solve this problem

Original Undulator Front End



Flux @ 30 m, c. 1996*

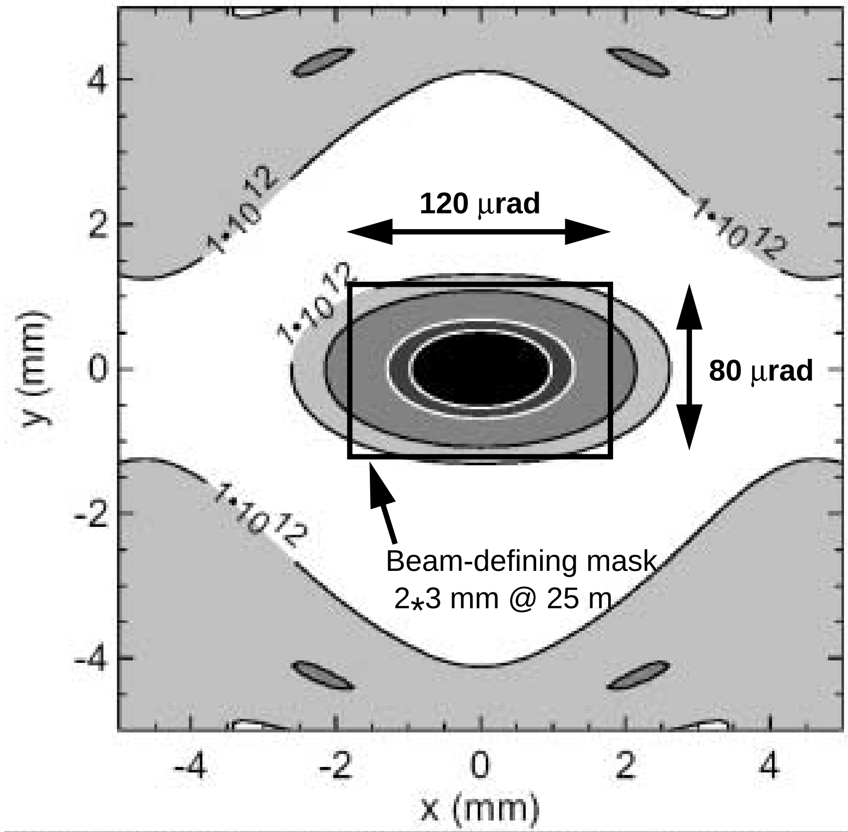


Figure 7. Spatial photon distribution at 30 m from the source for Keff = 2.74 (closed gap 10.5 mm) at the **first harmonic** energy (2.95 keV) for the **8.2 nm-rad design lattice**. The peak intensity is 3.4×10^{14} ph/s/mm2/0.1%bw. The innermost contour line is the FWHM of the central cone. The second innermost white contour line is at the 10^{14} level (other contour lines are a factor of 10 apart). y (mm)

c. 2003

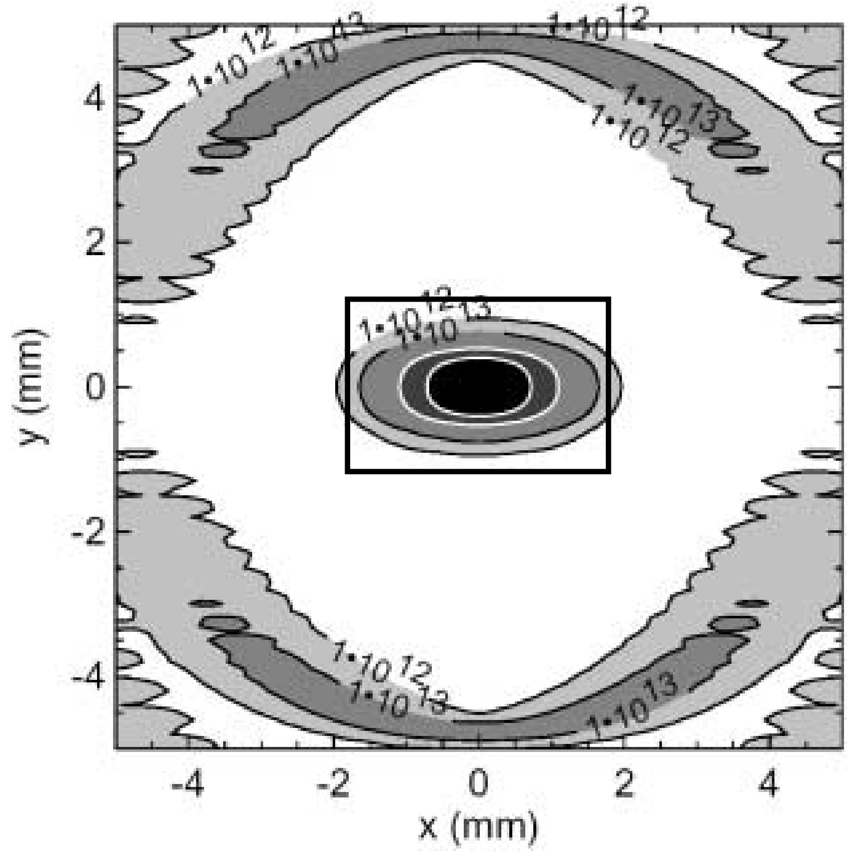
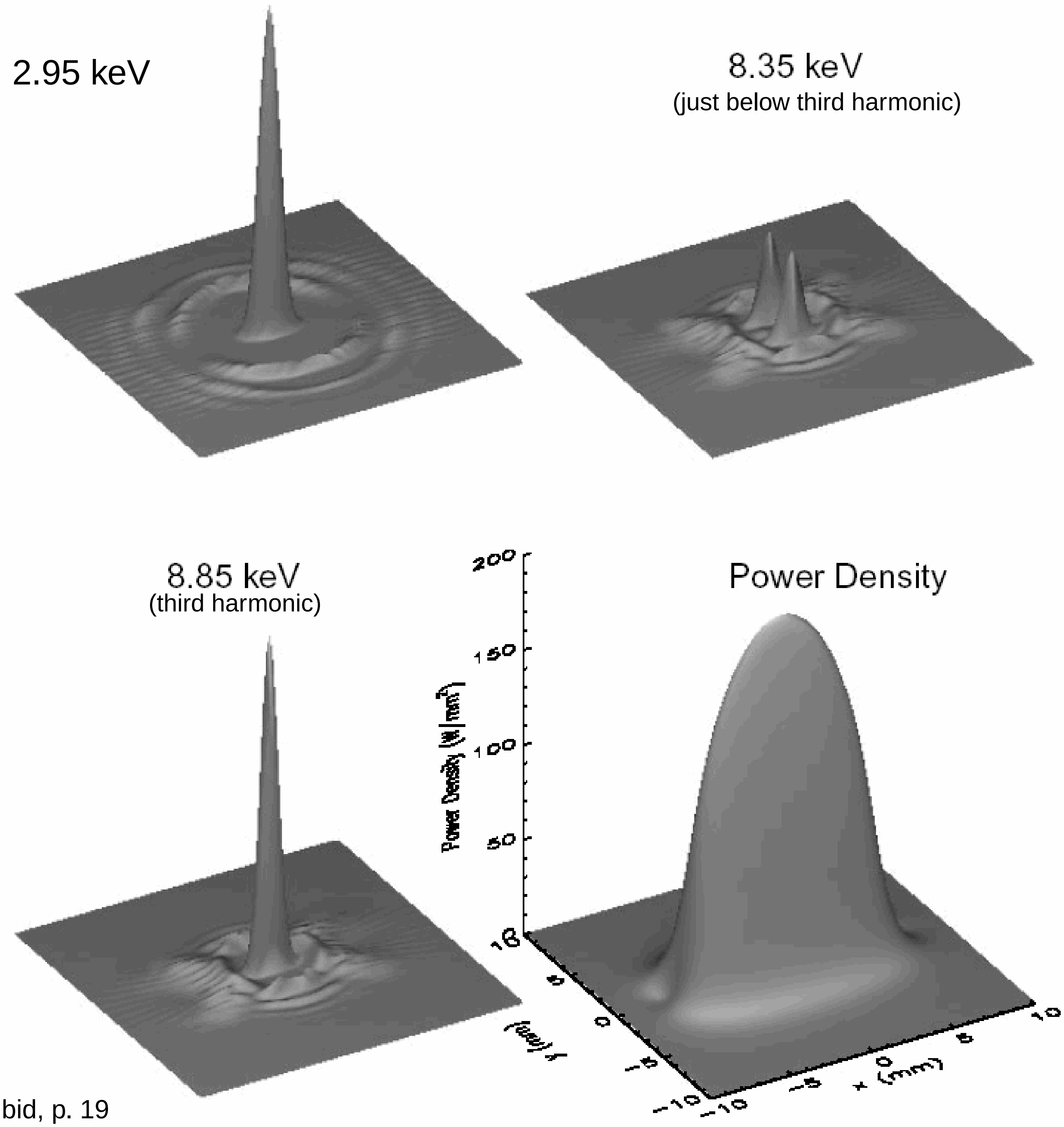


Figure 9. Spatial photon distribution at 30 m from the source for Keff = 2.74 (closed gap 10.5 mm) at the first harmonic energy (2.95 keV) for the present **3.5 nm-rad low emittance lattice**. The peak intensity is 5.1×10^{14} ph/s/mm2/0.1%bw. The innermost contour line is the FWHM of the central cone. The second innermost white contour line is at the 10^{14} level (other contour lines are a factor of 10 apart). The central cone, including the second harmonic off-axis, appears more distinctly for the smaller emittance. (The jaggedness is partially an artifact from the calculations due to the finite number of points used.)

* R. Dejus etal, http://www.aps.anl.gov/xfd/tech_bulletins/tb45.pdf

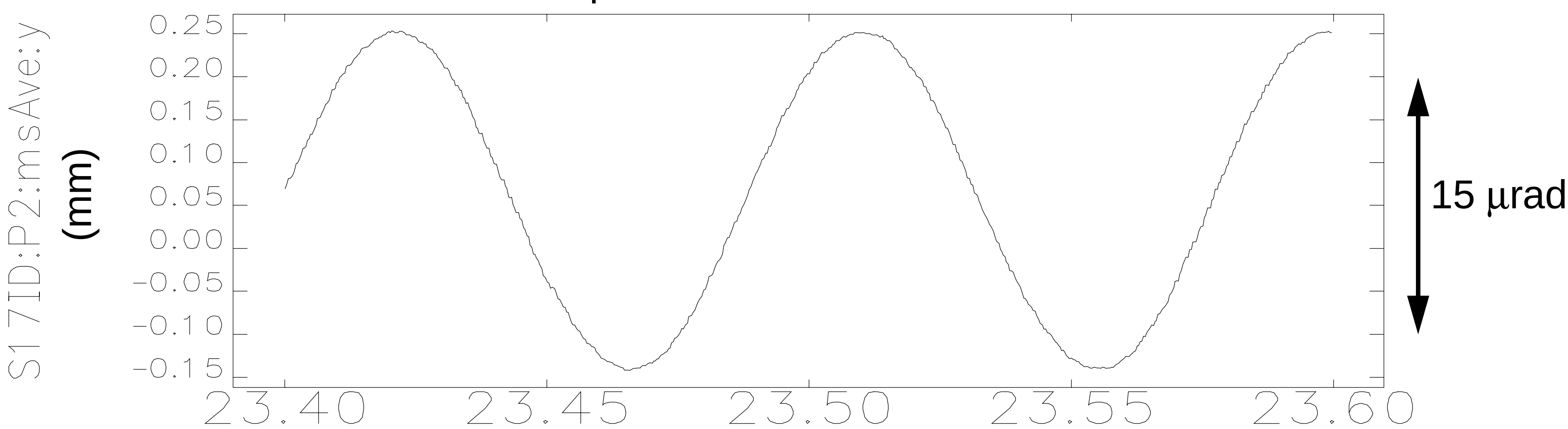
First, third harmonic flux compared w/ power



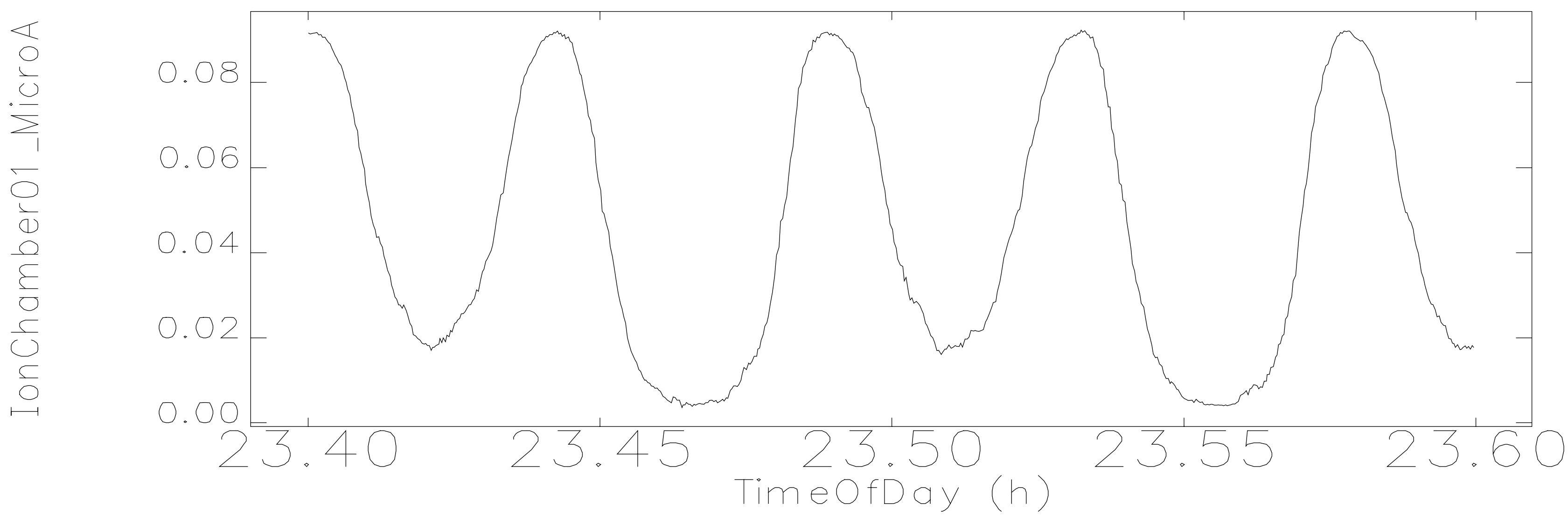
Ibid, p. 19

Beamline Alignment using an Ion Chamber and an Aperture

Vertical position 20 meters from the source



Beamline ion chamber, behind an aperture



Strategy to achieve 200 nrad / week stability

- The beam-defining mask provides a datum for pointing angle.
  - Misalignment on this mask induces hypersensitivity to beam motion.
  - It is generally quite difficult to assure this alignment using existing beamline hardware.
  - A power measurement downstream of this mask is a potentially very accurate “absolute” beam position diagnostic, albeit a destructive one.
  - Such a diagnostic can be used to validate a new non-destructive hard x-ray position monitor design, with few-micron long-term stability.

- The existing “P2” front-end photon bpm housing is an ideal final home for a non-destructive hard x-ray bpm.
  - Present P2 performance is poor; an upgrade is needed.
  - Mechanical translation stages and controls exist.
  - Four-channel data acquisition and substantial processing software exists.

Scope of Work

- Proposal is to validate the method at 19 ID, combining both techniques in a device (designed by G. Rosenbaum) to be located approx. 50 meters from the source.
- This is to be followed immediately by the generation of production drawings for two separate devices:
  - Retractable power monitor to be located immediately downstream of beam-defining mask.
  - Non-destructive in-vacuum hard x-ray bpm assembly, for use at P2 location.
- Final implementation to be determined by performance at 19ID, driven by demand, funding availability.
  - Power monitor alone valuable for fiducialization of existing UV photon bpm’s.